State of California
The Resources Agency
Department of Water Resources

DEVELOPMENT OF THE FEATHER RIVER FLOW-STAGE MODEL

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

A flow-stage model for the Feather River was developed and calibrated in this study. The flow-stage model will subsequently be used to support the fishery and ecosystem modeling on the Feather River for DWR's Oroville Facilities Relicensing efforts. The model used the river geometry data from the USACE Comprehensive Study and other available source information to develop a model of the Feather River comprising the reach from the Oroville dam to the confluence with Sacramento River, including all the hydraulic structures on the river. The model was then calibrated using the recorded flow-stage data at the gages on the Feather River for flows in the range of 2000 cfs, 4000 cfs, 6000 cfs, and 10000 cfs. Additional calibration was done for flows around 2000 cfs using water surface elevation data collected as part of the riparian transect surveys conducted by DWR in October 2002. Major achievements and findings include:

- A stand-alone flow-stage model was developed for the entire Feather River.
- The computed river stages from the flow-stage model compared well with the recorded river stages at gages on the Feather River for flows of around 2,000 cfs, 4,000 cfs, 6,000 cfs, and 10,000 cfs.
- The Feather River flow-stage model can be used to create calibrated flow-stage rating curves on the Feather River for flows ranging between 2,000 cfs and 10,000 cfs.
- When applying the model to low flows in the upper Feather River (above Gridley gage), it is important to understand that the combination of the natural river flow regime and the lack of gages for calibration may result in stage predictions that vary from actual stages in that reach.
- The flow-stage relationships will be extended to flows less than 2,000 cfs and greater than 10,000 cfs. The allowed margin is approximately 500 cfs (1/4 of flow interval of 2,000 cfs) for low flows, and the allowed margin is 1,000 cfs (1/2 flow interval of 2,000 cfs) for high flows. Further increasing the margin will decrease the reliability in flow-stage modeling results. This is particularly true if flow is less than 2,000 cfs because the channel bottom will have more dominant effects on water surface elevations.

Collection of water surface elevations at additional locations is recommended to improve the HEC-RAS model low flow calibration in the upper Feather River. In addition, a hydrographic re-survey of the reach from RM 0.0 to RM 8.0 is recommended to obtain the up-to-date river channel topographic data to supplement or replace the information in the model.

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TABLE OF CONTENTS

REPORT SUMMARY i
1.0 INTRODUCTION 1-1
1.1 BACKGROUND 1-1
1.2 OBJECTIVE AND OVERVIEW OF TECHNICAL MEMORANDUM 1-1
2.0 FEATHER RIVER FLOW-STAGE MODEL DEVELOPMENT 2-1
2.1 MODELING AREA DESCRIPTION 2-1
2.2 SOURCE INFORMATION USED 2-1
2.2.1 Channel Geometry Data 2-1
2.2.2 Available Flow and Stage Records 2-1
2.2.3 Other Source Information 2-2
2.3 SEPARATED HEC-RAS MODEL REVISION 2-2
2.3.1 Reach Combinations 2-2
2.3.2 Adding Inline Weirs 2-7
2.3.3 Adding Bridges 2-7
2.3.4 Channel Cross Sections Modifications 2-8
2.4 SUMMARY OF THE REVISED MODEL 2-8
2.5 MODEL CALIBRATION AND VALIDATION 2-8
2.5.1 Calibration Technique 2-8
2.5.2 Calibration Runs 2-9
2.5.3 Calibration Efforts 2-10
2.5.3.1 Adjusting Manning's n roughness coefficients 2-10
2.5.3.2 Rock Diversion Weir at RM 38.76 2-10
2.5.3.3 The Riffle Below Yuba City Gage 2-11
2.5.3.4 Channel Geometry Modification 2-11
2.5.4 Calibration Results 2-12
2.5.5 Model Validation 2-12
2.6 MODEL LIMITATIONS 2-13
3.0 SUMMARY OF TECHNICAL MEMORANDUM 3-1

APPENDICES

Appendix A - Example 1
Appendix B - Example 2

LIST OF TABLES

Table 2.2-1. Gages used for the Feather River flow-stage model development. 2-2
Table 2.5-1. Recorded river stages at gages on Feather River for model calibration flows. 2-9
Table 2.5-2. Comparison Between Computed and Recorded River Stages at Gages on the Feather River. 2-13
Table 2.5-3. Comparison between computed and measured river stages at riparian transects on Feather River. 2-14

LIST OF FIGURES

Figure 2.1-1 Study Area for the Feather River Flow-Stage Model 2-3
Figure 2.2-1 Hydraulic Structures and River Gages on the Feather River 2-5
Figure 2.5-1. Water surface profile for 2,000-cfs calibration run 3-3
Figure 2.5-2. Water surface profile for 4,000-cfs calibration run 3-5
Figure 2.5-3. Water surface profile for 6,000-cfs calibration run 3-7
Figure 2.5-4. Water surface profile for 10,000-cfs calibration run 3-9
Figure 2.5-5. Validation water surface profile 3-11

1.0 INTRODUCTION

1.1 BACKGROUND

The Oroville Facilities are a multipurpose water supply, flood control, power generation, recreation, fish and wildlife, and salinity control project. The major facilities include Lake Oroville, Oroville Dam, three powerplants (Edward Hyatt Powerplant, Thermalito Diversion Dam Powerplant, and Thermalito Pumping-Generating Powerplant), Thermalito Diversion Dam, Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Thermalito Forebay and Forebay Dam, and Thermalito Afterbay and Afterbay Dam, as well as a number of recreational facilities. The facilities operate under a license from Federal Energy Regulatory Commission (FERC), and the license for the facilities expires on January 31, 2007. Pursuant to the Federal Power Act, California Department of Water Resources (DWR) is required to file an application for a new license (relicense) on or before January 31, 2005.

Currently, DWR is conducting the relicensing process for the Oroville Facilities, FERC Project No. 2100, to allow the continued use of the hydroelectric generation facilities. To support the relicensing process, an integrated set of models was recommended to evaluate various operational alternatives. The recommended analyses of the Oroville Facilities and the Feather include storage, flow, power, and temperature. Temperature modeling will be conducted on both the Oroville Facilities and the Feather River.

Feather River temperature modeling relies on the flow-stage relationship, therefore development of a flow-stage model for the Feather River becomes essential. A hydraulic model of the Feather River serves well in developing a relationship between flow and stage. Study Plan SP-E1 (Engineering and Operations Model Recommendations) has identified using HEC-RAS as the modeling tool to develop the Feather River flow-stage model.

1.2 OBJECTIVE AND OVERVIEW OF TECHNICAL MEMORANDUM

The objective of this technical memorandum is to document the development and calibration of a Feather River flow-stage model for the subsequent temperature modeling. This technical memorandum is organized into the following sections:

- Introduction – provides a brief description of the background and the objective of this technical memorandum;
- Model Development – describes the development of the flow-stage model for the Feather River including the source data, model revision, and model calibration;
- Summary of technical memorandum – summarizes the development of the flow-stage model and the major achievements and findings.

Recommendations are also provided for flow-stage model performance improvement.

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2.0 FEATHER RIVER FLOW-STAGE MODEL DEVELOPMENT

2.1 MODELING AREA DESCRIPTION

The Feather River flow-stage model covers the reach from Oroville Dam to the confluence with the Sacramento River, with a total reach length of 72 miles. The channel bottom elevations drop from approximately 200 feet below the Oroville Dam to ten feet at the confluence with the Sacramento River. Major tributaries along the Feather River include Honcut Creek, Jack Slough, Yuba River, and Bear River (See **Figure 2.1-1**). Flows in Feather River are mainly determined by releases at Oroville Dam, the operation of Oroville Facilities, major diversions along the river, and inflows at major tributaries downstream from the Oroville Dam.

2.2 SOURCE INFORMATION USED

2.2.1 Channel Geometry Data

Channel geometry data for development of the Feather River flow-stage model used the HEC-RAS model developed in the Sacramento-San Joaquin Basins Comprehensive Study (Comprehensive Study). In the Comprehensive Study, the U.S. Army Corps of Engineers (USACE) developed an interim HEC-RAS model for the entire Sacramento River Basin, including the Feather River. The interim HEC-RAS model was used to provide geometry data for the development of the Sacramento River UNET model, which was used later for the hydraulic modeling in the Comprehensive Study. For the purpose of developing the flow-stage model for the Feather River, the Feather River portion excluding its tributaries was separated from this interim Comprehensive Study HEC-RAS model. This separated Feather River HEC-RAS model did not include hydraulic structures (inline weirs and bridges) on the river, so it was not ready to be used for the flow-stage modeling until they were incorporated in the model, plus other modifications to the model and the model calibration.

2.2.2 Available Flow and Stage Records

Another data source includes flow and stage records at the gages on the Feather River. Eight gages were identified on the Feather River, Yuba River, and Sacramento River, and they were used later in the flow-stage development. The gage names and other associated information are shown in Table 2.2-1 (See Figure 2.2-1 for the locations of these gages). The information about each gage was obtained from the California Data Exchange Center (CDEC). Water stages recorded at these gages are based on the USED datum, while the geometry of channel cross sections in the flow-stage model are based on the NGVD datum. To be consistent, the recorded stages were converted to NGVD datum based by subtracting 3.0 feet. The flow and stage data used for the model calibration were related to the specific calibration runs, so these data are presented in the later section. Notice that some gages record both flow and stage data, while the rest of them record either only stage data or only flow data. Flow data will be

Table 2.2-1. Gages used for the Feather River flow-stage model development.

Gage Name	CDEC Gage ID	Approximate River Mile	River Basin
Gage at Oroville Dam	ORO	71.5	Feather River
Gridley Gage	GRL	50.64	Feather River
Live Oak Gage	FLO	38.99	Feather River
Yuba City Gage	YUB	27.50	Feather River
Boyd's Landing Gage	FBL	20.75	Feather River
Bear River at Camp Far West Dam	CFW	N/A [1]	Bear River
Marysville Gage	MRY	2.0 [2]	Yuba River
Nicolaus Gage	NIC	8.25	Feather River
Verona Gage	VON	79.25	Sacramento River

1- The river mile on Bear River can not be determined from the Comp Study HEC-RAS model. Bear River enters Feather River at river mile 12.0
2- Yuba River enters Feather River at river mile 27.0

used as flow inputs for the model runs, while stage data will be used as calibration reference or boundary conditions.

2.2.3 Other Source Information

Other source information used in the flow-stage model development also include: as-built drawings for the inline weirs and bridges, aerial photos, pictures taken on-site as well as bridge data developed for a FEMA study. These source information were used to add the inline weirs and major highway bridges into the Feather River flow-stage model. The aerial photos helped identify the rock diversion dam at river mile (RM) 38.76 and the riffle below Yuba Gage that could have significant effects on water surfaces in the model calibration. The locations of major inline weirs and bridges as well as the gages are shown in Figure 2.2-1.

2.3 SEPARATED HEC-RAS MODEL REVISION

The separated Feather River HEC-RAS model from the Comprehensive Study HEC-RAS model was revised by combining the multiple reaches of the Feather River into one single reach and by adding the inline weirs and bridges into the model, as well as by modifying limited channel cross sections.

2.3.1 Reach Combinations

In the Comprehensive Study, the Feather River was divided into four reaches to allow its connection with the major tributaries. These four reaches were combined into one single reach after the Feather River was separated from the entire Sacramento River HEC-RAS model. The major tributaries were also removed from the model to create a stand-alone model for the Feather River. The advantages of removing the major tributaries are:

- Focuses on Feather River as the study reach.

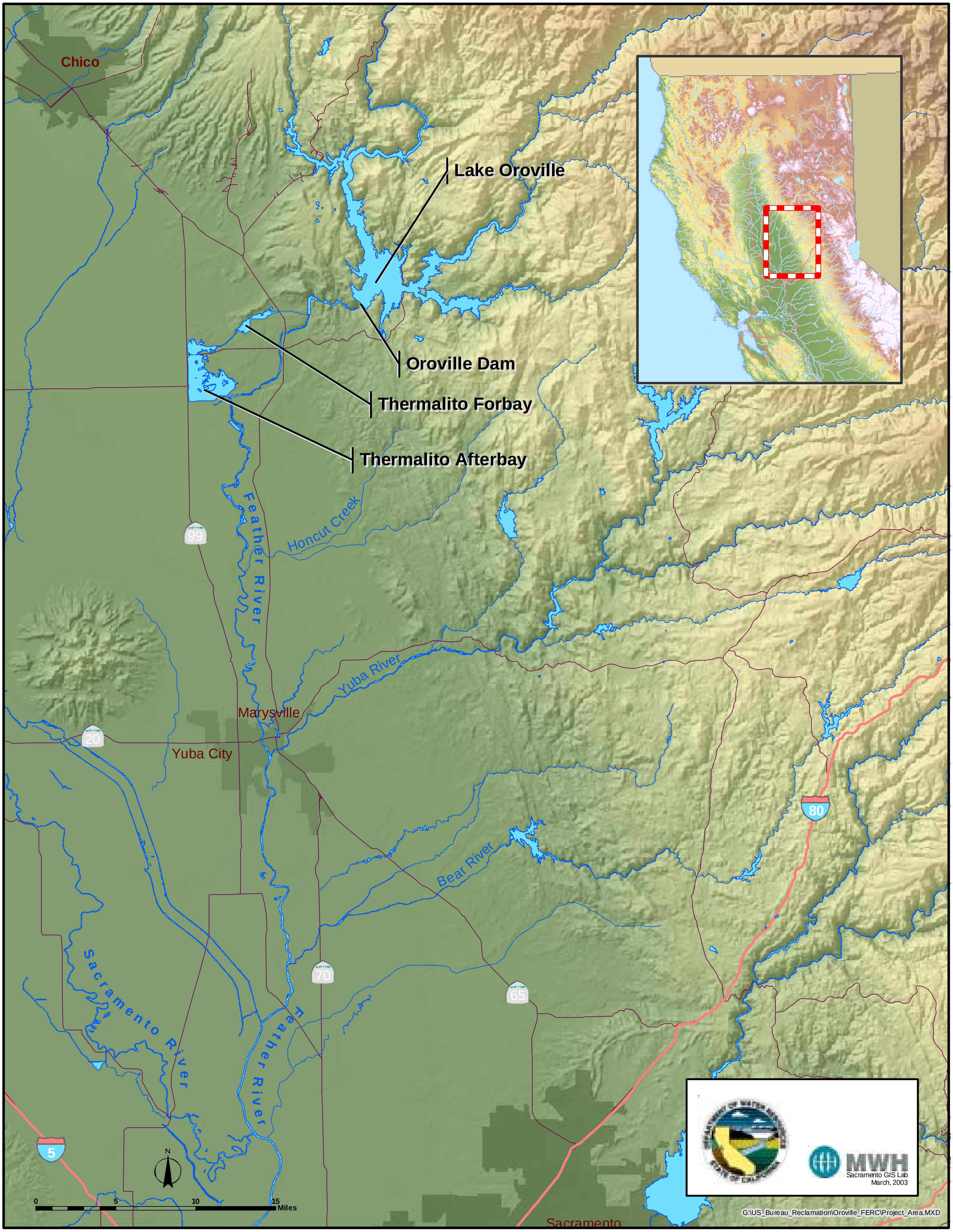

Figure 2.1-1. Study area for the Feather River flow-stage model

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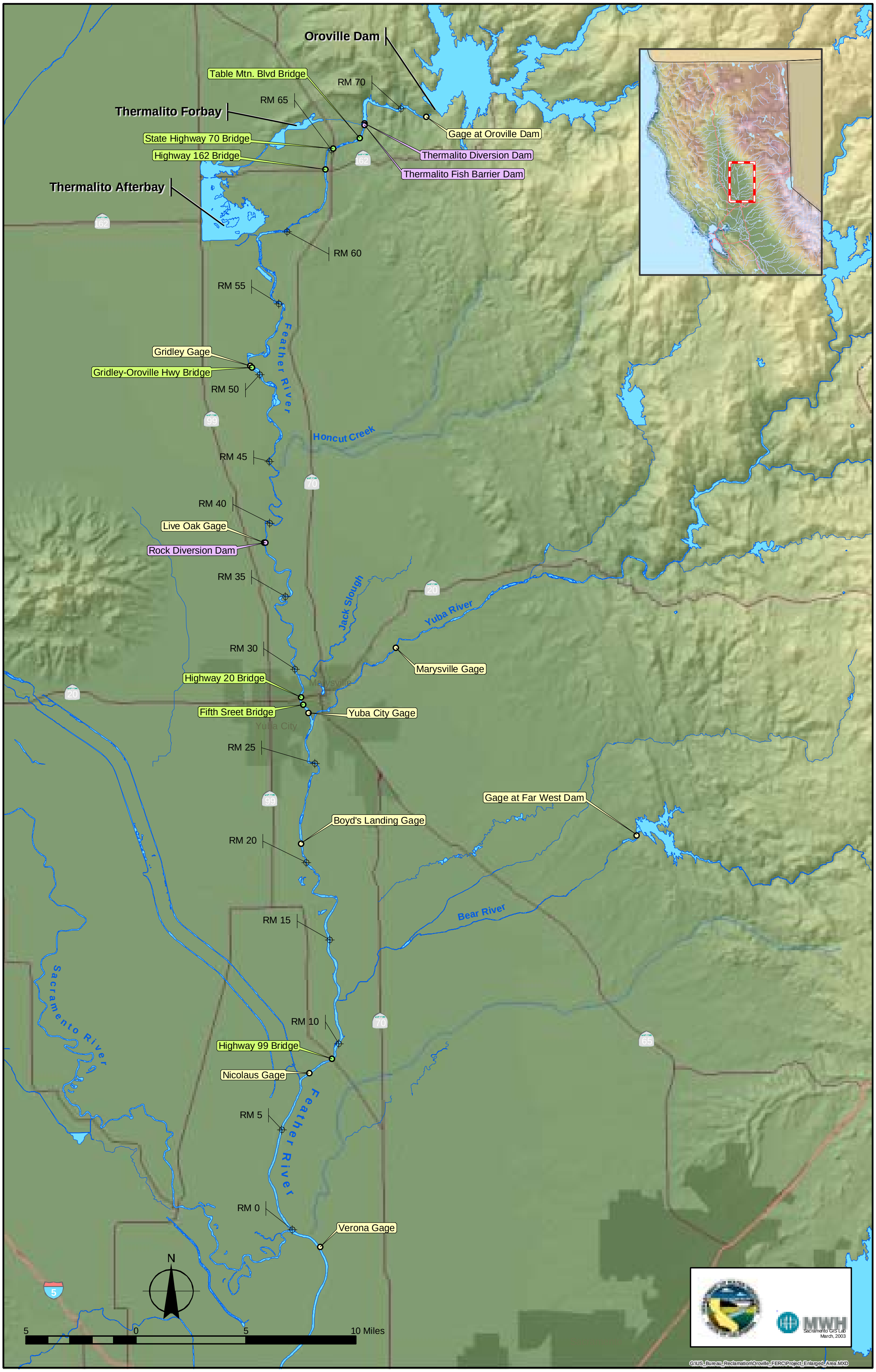

Figure 2.2-1. Hydraulic structures and river gages on the Feather River

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- Simplifies boundary conditions inputs by having only one reach.
- Provides easier display of the modeling results and locate specific cross sections locations.

2.3.2 Adding Inline Weirs

Inline weirs (diversion dams and overflow weirs) can have significant effects on water surface because water is ponded behind the weir or dam creating a backwater effect that will result in a raise in the water surface upstream. Diversion dams and weirs that were added into the Feather River flow-stage model include:

- Thermalito Diversion Dam –located about five miles downstream from Oroville Dam, at RM 67.0. It is a gated controlled weir with fourteen 40 x 20 foot radial gates in the middle.
- Fish Barrier Dam –an overflow weir with a rectangular notch (250 feet wide, 20 feet high) in the middle. The fish barrier dam is immediately downstream from Thermalito Diversion Dam.
- Rock Diversion Dam – is located in the reach between the Gridley-Oroville Highway Bridge and the Highway 20 Bridge, at around RM 38.76.

2.3.3 Adding Bridges

Bridges can also have significant effects on river hydraulics, especially when river flows are high enough to touch the lower chord of the bridge roadway. During low-flow conditions, the presence of bridge piers in the channel will decrease the area and increase the wetted perimeter causing a decrease in conveyance.

The following bridges were added into the model:

- Table Mountain Blvd Bridge;
- State Highway 70 Bridge;
- Highway 162 Bridge;
- Gridley-Oroville Highway Bridge;
- Highway 20 Bridge;
- Fifth Street Bridge in Yuba City;
- Highway 99 Bridge

As low flows are the major concern for flow conditions in the temperature modeling on the Feather River, more emphasis was given to the number, width, and location of piers for each bridge than to the bridge roadway configuration, which will only affect river hydraulics for high flows. The energy method for bridge hydraulic computation was used for all the model runs in this study since it is most capable of correctly handling low flows through bridges.

2.3.4 Channel Cross Sections Modifications

Channel cross sections modifications involved significant efforts of model testing runs, and it was also overlapped with model calibration. Modifications to limited channel cross sections include:

- Adding levees on channel banks (top elevation of levee point is about the same as the bank elevation) to contain flows in the main channel before it overflows to overbank areas.
- Adjusting Manning's *n* values for the cross sections calibration purpose (see model calibration section for more detail).
- Adjusting the channel bottom elevation of limited cross sections to match the observed water surfaces in the process of model calibration (see model calibration section for more detail).

2.4 SUMMARY OF THE REVISED MODEL

The revised Feather River flow-stage model is a single reach model with total reach length of 72 miles. The final model consists of 373 cross sections, three inline weirs/dams (the Thermalito Diversion dam, The Fish Barrier Dam and the rock diversion dam at RM38.76), and seven bridges (Table Mountain Blvd Bridge, State Highway 70 Bridge, Highway 162 Bridge, Gridley-Oroville Highway Bridge, Highway 20 Bridge, Fifth Street Bridge in Yuba City, and Highway 99 Bridge). The original Manning's *n* roughness value was 0.035 in the main channel, and 0.050 in the overbank areas.

2.5 MODEL CALIBRATION AND VALIDATION

2.5.1 Calibration Technique

The model calibration runs were conducted under steady-state flow analysis mode, and the model inputs consisted of system inflows at upstream end, flow changes along the river, and downstream boundary conditions. For each run, the input data was selected from the recorded historical time-series data at the gages on the Feather River. A specific time period ("snap-shot") of stable recorded data was selected to ensure the steady flow assumption in the calibration runs.

The Oroville Reservoir releases were treated as system inflows at the upstream end, and the flow changes along the Feather River resulted from water diversions off the channel, the joining of tributary flows, and the effect of channel storage on channel flow were treated as internal boundaries. For low flow conditions, the tributary inflows except for Yuba River inflows were negligible compared to the flow in the Feather River. Besides, no recorded data (or under rating curve) for low flows were available on the other two tributaries (Honcut Creek, Jack Slough and Bear River) near their confluences with the Feather River. Water surface elevations of the Sacramento River at the confluence with the Feather River were used as the downstream boundary conditions. The closest gage (Verona gage) is about 0.75 miles below the confluence, therefore, the water surface elevation of the Sacramento River at the confluence were estimated by adding 0.3 feet to stages recorded at the Verona gage.

2.5.2 Calibration Runs

Four calibration runs were performed to compare the computed water stages with the recorded river stages at the Feather River gages. As low flows are the major concern in the Feather River temperature modeling, four calibration runs were selected by the approximate flows released from Oroville Reservoir. The calibration runs are identified as 2,000-cfs (cubic feet per second) run, 4,000-cfs run, and 6,000-cfs run and 10,000-cfs run. It should be noted that flow releases from Oroville Reservoir are not exactly 2000 cfs, 4000 cfs, 6000 cfs and 10,000 cfs respectively. Moreover, the flow in the Feather River changes after the addition of Yuba River inflows for all runs and after the addition of the Bear River for 10,000-cfs run. The recorded river stages at the gages on the Feather River corresponding to these river flows are summarized in Table 2.5-1.

Table 2.5-1. Recorded river stages at gages on Feather River for model calibration flows.

Gage Name	River Mile	River Basin	Calibration Model Runs							
			2000-cfs		4,000-cfs		6,000-cfs		10,000-cfs	
			Flow (cfs)	Stage (feet)*	Flow (cfs)	Stage (fee)*	Flow (cfs)	Stage (feet)*	Flow (cfs)	Stage (feet)*
Gage at Oroville Dam	71.5	Feather River	2,075	-	4,018	-	6,005	-	13,144	-
Gridley Gage	50.64	Feather River	2107	71.36	4,029	72.55	5,715	73.55	11,258	76.11
Live Oak Gage	38.99	Feather River	-	48.99	-	50.61	-	52	-	55.91
Yuba City Gage	27.5	Feather River	-	35.84	-	36.95	-	38.49	-	43.57
Boyd's Landing Gage	20.75	Feather River	-	25.86	-	27.1	-	29.1	-	37.88
Nicolaus Gage	8.25	Feather River	-	17.47	-	18.59	-	20.39	-	34.08
Bear River at Camp Far West Dam	-	Bear River	-	-	-	-	-	-	1,640	-
Marysville Gage	2	Yuba River	1,476	-	1183	-	1,424	-	6,142	-
Verona Gage	79.25	Sacramento River	11,270	9.54	10,540	9.15	16,720	12.4	16,720	30.99

** Stages in NGVD datum system.*

2.5.3 Calibration Efforts

The three calibration runs mentioned above were performed under steady-state analysis mode, and the computed river stages were compared with the recorded river stages at each gage. Efforts were made to reduce the discrepancies include the following and are discussed separately:

- Adjusting Manning's *n* roughness coefficients,
- Dealing with the rock diversion weir at RM 38.76,
- Dealing with the riffle below Yuba City gage and,
- Modifying channel geometry

2.5.3.1 Adjusting Manning's n roughness coefficients

Adjusting channel Manning's *n* roughness coefficients is the most widely used and preferred method for hydraulic model calibrations of natural rivers. It works well for reaches where the river resistance is the major factor that influences the water surface profiles. The Manning's n roughness coefficients in the entire Feather River main channel were 0.035 and 0.050 in the overbank areas. The Manning's *n* values in overbank areas will not affect the low-flow modeling results in this study because flows will be kept in the main channel of the Feather River. The Manning's *n* value adjustments, therefore, were limited to the main channel of the Feather River. Although the Manning's *n* value of 0.035 was not a perfect representation of Feather River channel resistance everywhere, adjustments were only made to the following reaches instead of the entire reach:

- From RM 48.26 to RM 49.26, the flow-varied Manning's *n* value method was used to calibrate to stages at the Gridley gage. The Gridley gage is about 500 feet upstream from the Gridley-Oroville Highway bridge (note old bridge piers are not removed in the upstream, and they were added into the flow-stage model as well). Manning's *n* values of 0.045, 0.040, and 0.030 were used in the channel cross sections within this reach for 2000-cfs, 4000-cfs, and 6000-cfs calibration flows respectively.
- From RM 0 to RM 20.50, the flow-varied Manning's *n* value method was used in order to match the recorded river stages at the Boyd's Landing and Nicolaus gages. The Manning's *n* values vary in the different portion of this reach.

2.5.3.2 Rock Diversion Weir at RM 38.76

A rock diversion weir was identified at approximately RM38.76, and the Feather River gage at Live Oak is located immediately upstream from the rock diversion weir. River stages at the Live Oak gage are greatly affected by the rock diversion weir, and the computed river gage in the flow-stage model will be highly dependent upon the correct configuration of the rock diversion weir.

From an aerial photo taken for the reach where the rock diversion weir is located, it was estimated that the rock diversion weir was about 500 feet long and skewed to the flow direction at an angle of around 30° (the channel is about 300 feet wide at this location). The weir consists of roughly three sections with different top elevations. Weir overflow mainly occurs over the two lower sections in the right half of the weir for low flows. This rock diversion weir was originally simulated as an elevated roughly flat-bottomed cross section in the Comprehensive Study HEC-RAS model. The rock diversion dam was modified in the Feather River flow-stage model, and three methods were attempted to determine the most effective as follows:

- The channel was widened to 500 feet and a three-sectioned weir was placed at the widened cross section. Widening the channel was the only way to use a weir with the correct actual length (500 feet) due to the fact that skewed weirs could not be simulated in the current version of HEC-RAS (version 3.1). Because the channel was widened to allow simulation of the weir, expansion and contraction coefficients in the model were turned off for the cross sections representing the weir.
- The weir was simulated as a one-section weir perpendicular to the flow, with the weir length the same as the actual channel width. Adjusting the top elevation of the weir became part of the calibration efforts, along with adjusting the weir coefficient because of the rugged surface of the weir.
- The weir was simulated using an internal rating curve. As mentioned above, the Live Oak gage is located immediately above the rock diversion dam. The recorded stage data at Live Oak gage was used to establish the internal rating curve at the rock diversion dam.

The internal rating curve method was selected to simulate the rock diversion dam in the flow-stage model because the first two methods could not be able to produce satisfactory calibration results.

2.5.3.3 The Riffle Below Yuba City Gage

A riffle was also identified under low flow conditions by an aerial photo. The location of the riffle is at approximately RM 24.0, which is about 3.5 miles below the Yuba City gage. In the Comprehensive Study HEC-RAS model, this riffle was simulated in the model as an elevated roughly flat-bottomed cross section. For low flows, the riffle behaves similarly to a submerged weir, and it significantly affects the river stages at Yuba City gage. The calibration efforts involved adjusting the channel bottom elevation of this flat-bottomed cross section to match the recorded river stages at Yuba City gage.

2.5.3.4 Channel Geometry Modification

<u>Channel Geometry Modification in the Reach Near the Gridley Gage</u>

In the calibration efforts in matching the river stages at the Gridley gage, it was determined that the channel cross sections in the reach near the Gridley gage (between

RM 54.50 and RM 50.11) were not consistent with the topographic data. This discrepancy was verified with the USACE and the channel cross sections in this reach were modified based on the revised data provided by USACE. In addition, pictures taken on-site for the Gridely-Oroville Highway Bridge indicated the existence of old bridge piers in the main channel, and these piers were also added into the Feather River flow-stage model to account for their potential impacts on the water surface profile computations.

Channel Geometry Modification in the Reach Below the Nicolaus Gage

One of the difficulties encountered in the calibration was in the lower portion of the Feather River near the Nicolaus gage. The Nicolaus gage is about one mile below Highway 99 at Nicolaus. Prior to the model calibration, the computed river stages were about four feet higher than the recorded stages at the Nicolaus gage for all three flows used in the calibration runs. Additional test runs also indicated that it was impossible to reduce the computed water surface by four feet simply by adjusting Manning's *n* values in the reach below the Nicolaus gage. Furthermore, it would result in unrealistic Manning's *n* values for a natural channel.

Examination of the channel bottom profile revealed that the cross sections in the reach from RM 3.0 to RM 6.0 had significantly higher channel bottom than the reach from RM6.0 to the Nicolaus gage (RM8.25). The biggest difference was about four feet. Testing with various configurations showed that this was the major cause of the significantly higher computed water surfaces at the Nicolaus gage. Lowering the channel bottom elevation by four feet on this reach achieved fairly good calibration results, and it turned out this was the only way to match the computed stages with recorded stages at the Nicolaus gage. Unfortunately, it was nearly impossible to re-check the topographic data due to the availability of the topographic data for this reach.

2.5.4 Calibration Results

The results from the calibration runs are compared with the recorded river stages in **Table 2.5-2**. For most cases, the computed river stages are fairly close to the recorded data with the differences (computed stage minus recorded river gage elevation) less than around 0.5 feet with exception to 10,000-cfs run at Gridley gage where the difference was 0.82 feet for this run. **Figures 2.5-1** through **2.5-4** show the water surface profiles for the entire Feather River for calibration runs.

2.5.5 Model Validation

DWR staff conducted a field survey for cottonwoods between October 21, 2002 and October 31, 2002 at multiple locations on the Feather River shown in **Table 2.5-3**. The water surface elevations at the end of the riparian transects were taken during the survey. Recorded flows during that period were about 2000 cfs. The measured water surface elevations at the riparian transects were compared with the computed stages to validate the flow-stage model. The computed river stages match fairly well with the

Table 2.5-2. Comparison Between Computed and Recorded River Stages at Gages on the Feather River.

Calibration Runs		Gridley Gage RM 50.64	Live Oak Gage RM 38.99	Yuba City Gage RM 27.5	Boyd's Landing Gage RM 20.75	Nicolaus Gage RM 8.25
2000-cfs Run	Model Calculated Stage (feet)	71.02	48.96	35.88	26.31	17.42
	Recorded Stage (fee)	71.36	48.99	35.84	25.86	17.47
	Diff. (feet)	*-0.34*	*-0.03*	*0.04*	*0.45*	*-0.05*
4000-cfs Run	Model Calculated Stage (feet)	72.76	50.61	36.95	27.48	18.64
	Recorded Stage (feet)	72.55	50.61	36.95	27.1	18.59
	Diff. (feet)	*0.21*	*0*	*0*	*0.38*	*0.05*
6,000-cfs Run	Model Calculated Stage (feet)	73.63	51.85	37.97	29.67	20.94
	Recorded Stage (feet)	73.55	52	38.49	29.1	20.39
	Diff. (feet)	*0.08*	*-0.15*	*-0.52*	*0.57*	*0.55*
10,000-cfs Run	Model Calculated Stage (feet)	76.93	56.02	43.24	38.22	33.69
	Recorded Stage (feet)	76.11	55.91	43.57	37.88	34.08
	Diff. (feet)	*0.82*	*0.11*	*-0.33*	*0.34*	*-0.39*

measured river stages at these locations. The difference between computed and measured river stages is less than 0.50 feet at most locations (see **Table 2.5-3**). **Figure 2.5-5** shows the water surface profile for the validation run which also indicates a good match between the computed and measured river stages. The larger differences in computed and measured river stages mainly occur in the upper reach of the Feather River (Site 1A through Site 3B) and places where water surface changes rapidly (Site 4C and 5A).

2.6 MODEL LIMITATIONS

The calibrated Feather River flow-stage has limitations in the upper reach of the Feather River because of the natural river characteristics and the availability of sufficient source data. In the upper reach of the Feather River (above Gridley gage), the naturally formed riffles and pools cause the water surface changing significantly at numerous

Table 2.5-3. Comparison between computed and measured river stages at riparian transects on Feather River.

Site No.	Riparian Transects (River Mile)	Measured River Stage (feet)	Flow-Stage Model Computed River Stage (feet)	Difference between Computed And Measured River Stage (feet)
1A	65.34	127.5	126.81	-0.69
1B	65.34	127.4	126.81	-0.69
2A	63.81	125.4	125.81	0.41
2B	63.77	125.3	125.75	0.45
3A	52.2	73.6 [a]	-	-
3B	52.2	75.51	75.08	-0.43
4A	46.21	59.1	58.91	-0.19
4B	46.19	59	58.91	-0.19
4C	45.94	58.1	57.30	-0.8
5A	34.63	40.2	40.82	0.62
5B	34.54	39.7	40.01	0.31
6	28.70	36	35.87	-0.13
7A	25.95	35.16	34.66	-0.5
7B	21.82	25.7	25.82	0.12
8A	17.70	24	24.06	0.06
8B	17.70	24 [b]	24.06	0.06

a. This data appears to be an error.
b. The measured data showed the stage at Site 8B was 26 feet, which was higher than the stage at upstream Site 7B. So the stage at 8A was also used for Site 8B

locations. The water surface elevation above a riffle could be greatly affected by the riffle. Unlike a reach with a consistent general channel slope, where downstream water surface elevations may affect upstream water surface elevations for thousands feet, this influence can be disconnected by the riffles. Therefore, even though the computed river stages can be calibrated fairly close to the recorded data at the limited gage locations, there is no guarantee that computed water surface profiles will be representative elsewhere. (See **Figures 2.5-1** to **2.5-5** for the channel bottom characteristics and water surface profiles in the upper Feather River).

Secondly, natural channels are constantly experiencing dynamic changes in response to changes in flows, sediment loads, and other factors. In the lower reach of the Feather River, this effect appears to be more significant due to the frequent backwater effects from the Sacramento River. As the topographic data was obtained back in year 1997 and 1998, the channel geometry could have changed since the survey was taken. As modifying the channel geometry was the only effective way to match the recorded stages at Nicolaus gage, it cannot be determined if it was the result of the natural river movement or the incorrect topographic data.

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3.0 SUMMARY OF TECHNICAL MEMORANDUM

A flow-stage model for the Feather River was developed and calibrated in this study. The flow-stage model will subsequently be used to support the fishery and ecosystem modeling on the Feather River for DWR's Oroville Facilities Relicensing efforts. The model used the river geometry data from the USACE Comprehensive Study and other available source information to develop a model of the Feather River comprising the reach from the Oroville dam to the confluence with Sacramento River, including all the hydraulic structures on the river. The model was then calibrated using the recorded flow-stage data at the gages on the Feather River for flows in the range of 2000 cfs, 4000 cfs, 6000 cfs, and 10000 cfs. Additional calibration was done for flows around 2000 cfs using water surface elevation data collected as part of the riparian transect surveys conducted by DWR in October 2002. Major achievements and findings include:

- A stand-alone flow-stage model was developed for the entire Feather River.
- The computed river stages from the flow-stage model compared well with the recorded river stages at gages on the Feather River for flows of around 2,000 cfs, 4,000 cfs, 6,000 cfs, and 10,000 cfs.
- The Feather River flow-stage model can be used to create calibrated flow-stage rating curves on the Feather River for flows ranging between 2,000 cfs and 10,000 cfs.
- When applying the model to low flows in the upper Feather River (above Gridley gage), it is important to understand that the combination of the natural river flow regime and the lack of gages for calibration may result in stage predictions that vary from actual stages in that reach.
- The flow-stage relationships will be extended to flows less than 2,000 cfs and greater than 10,000 cfs. The allowed margin is approximately 500 cfs (1/4 of flow interval of 2,000 cfs) for low flows, and the allowed margin is 1,000 cfs (1/2 flow interval of 2,000 cfs) for high flows. Further increasing the margin will decrease the reliability in flow-stage modeling results. This is particularly true if flow is less than 2,000 cfs because the channel bottom will have more dominant effects on water surface elevations.

Collection of water surface elevations at additional locations is recommended to improve the HEC-RAS model low flow calibration in the upper Feather River. In addition, a hydrographic re-survey of the reach from RM 0.0 to RM 8.0 is recommended to obtain the up-to-date river channel topographic data to supplement or replace the information in the model.

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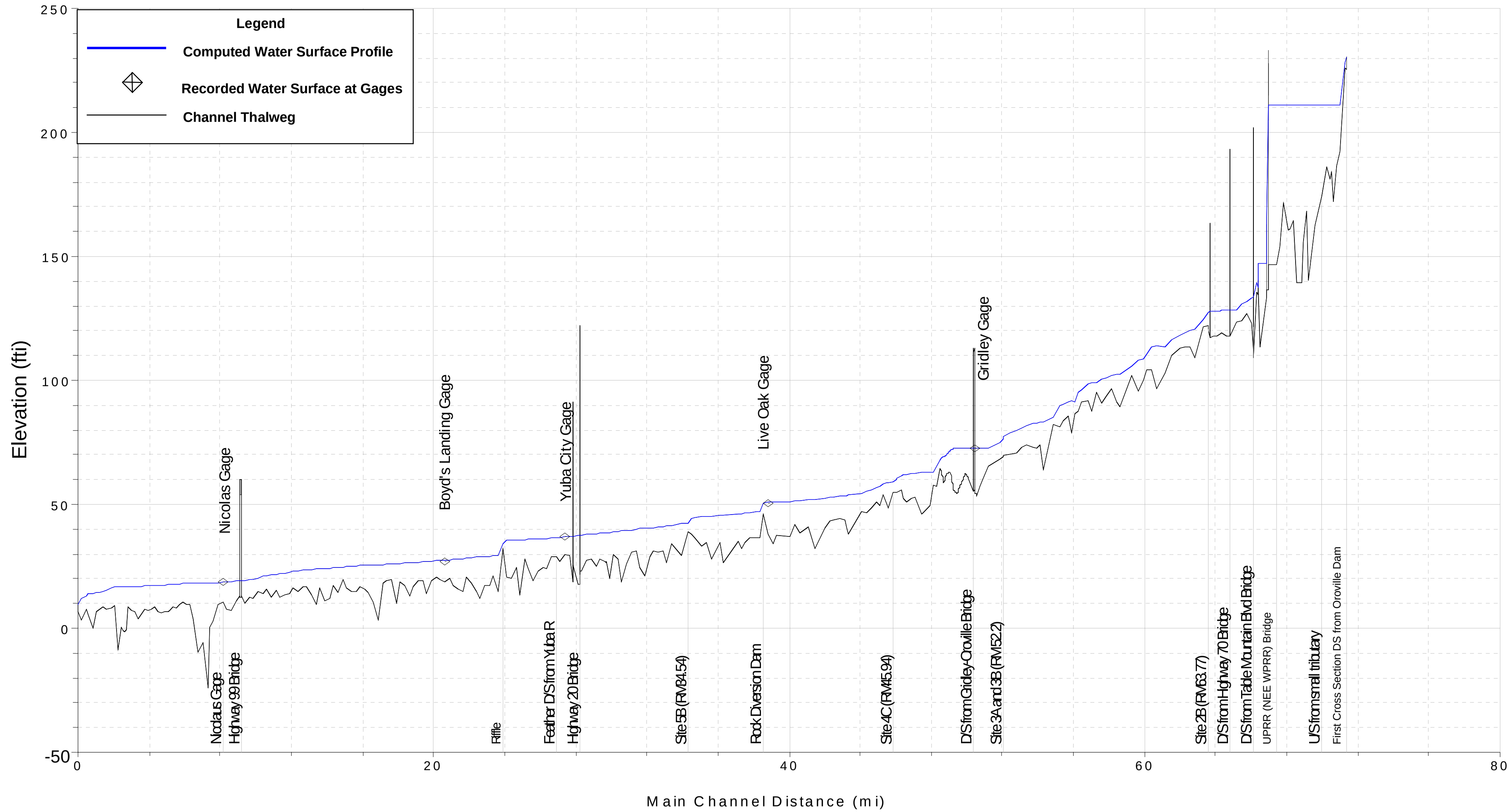

Figure 2.5-1. Water surface profile for 2,000-cfs calibration run.

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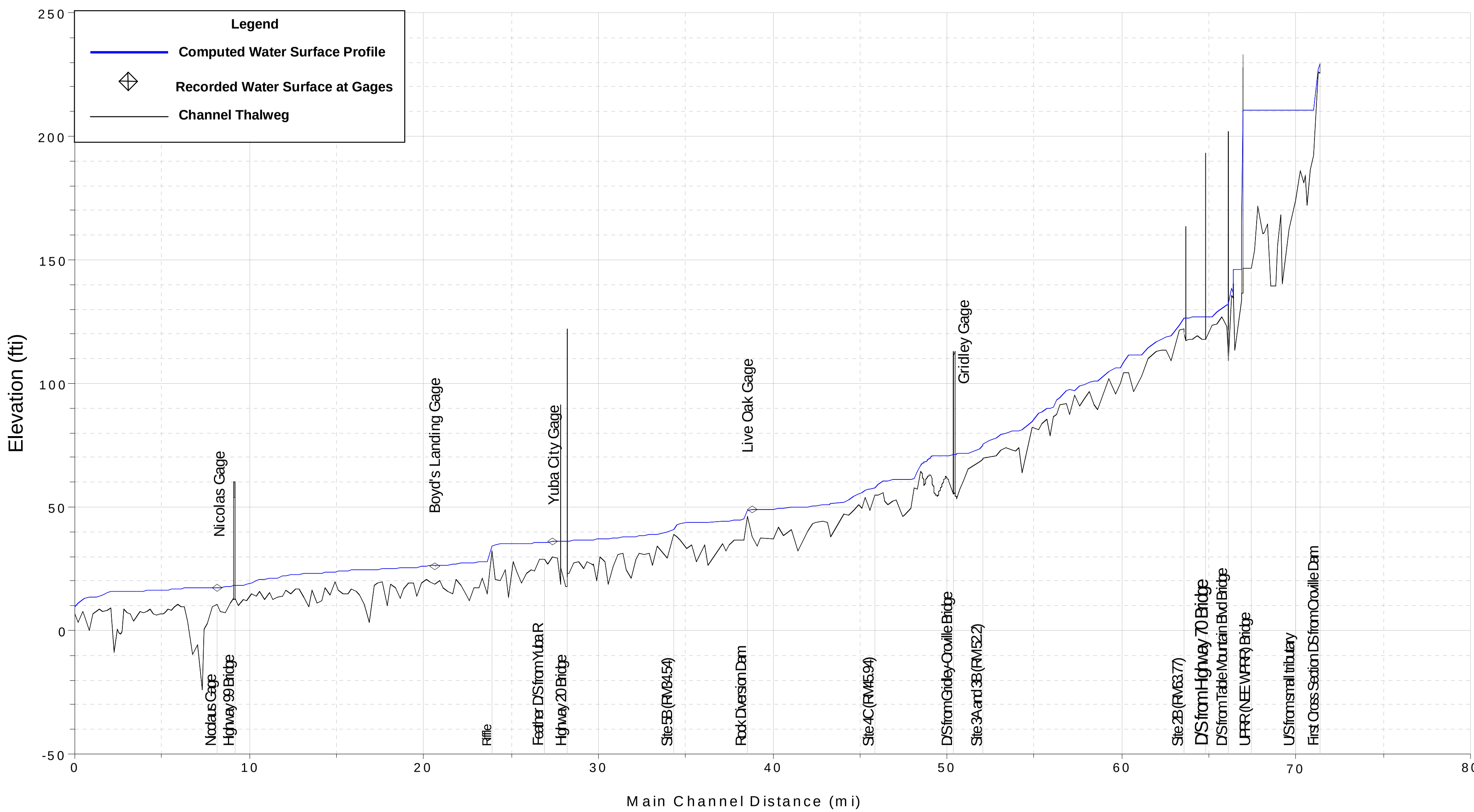

Figure 2.5-2. Water surface profile for 4,000-cfs calibration run.

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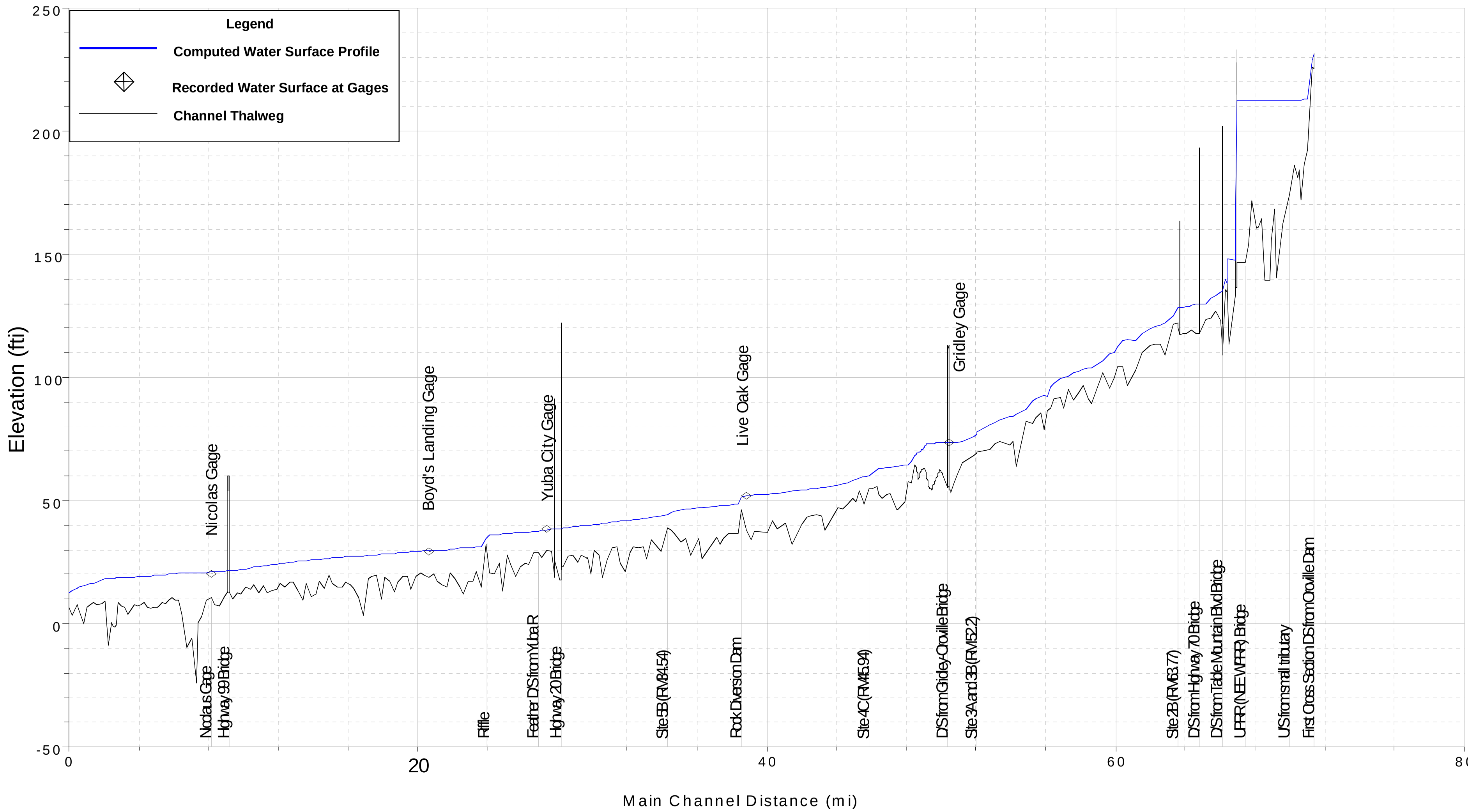

Figure 2.5-3. Water surface profile for 6,000-cfs calibration run.

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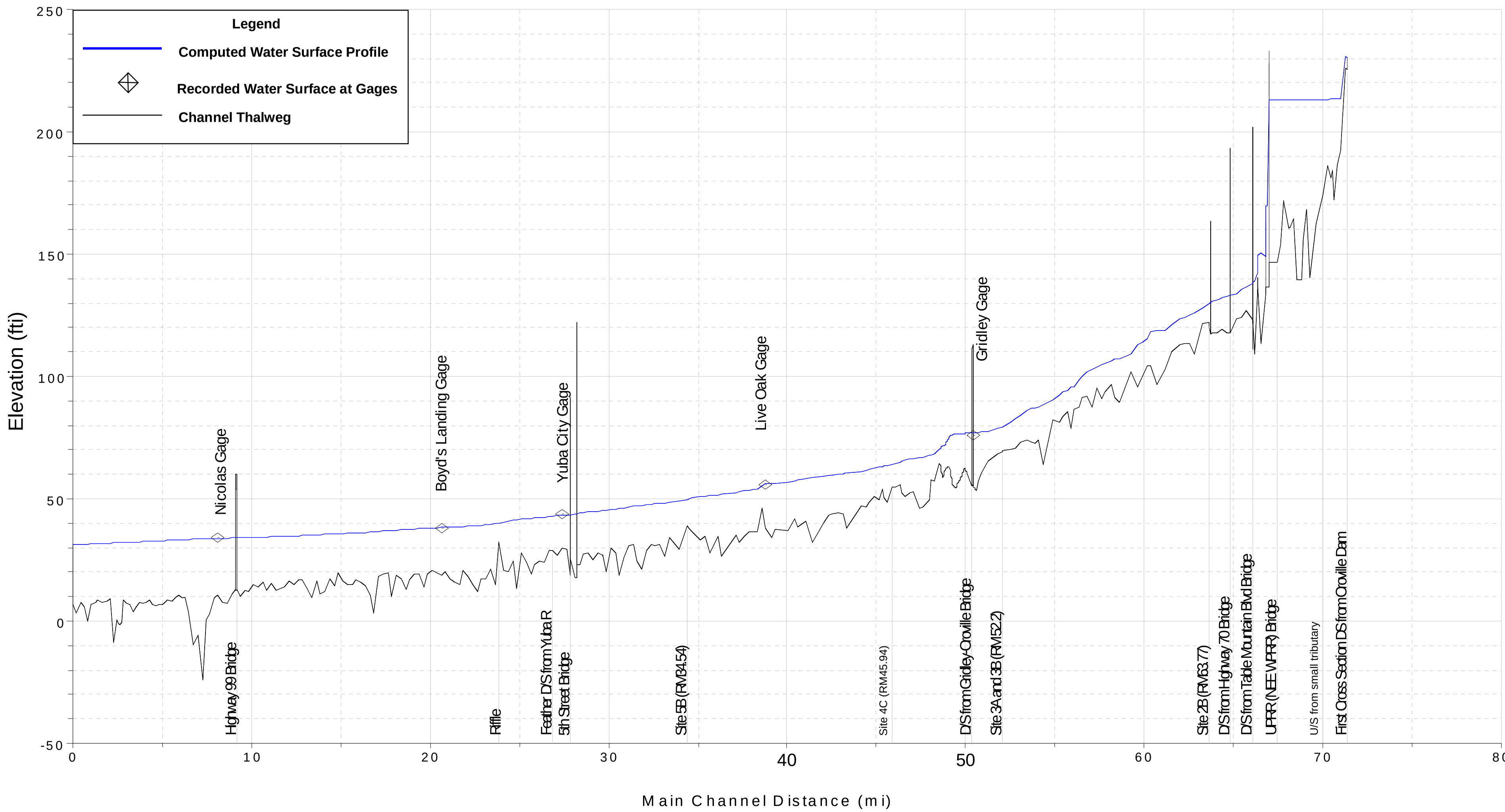

Figure 2.5-4. Water surface profile for 10,000-cfs calibration run.

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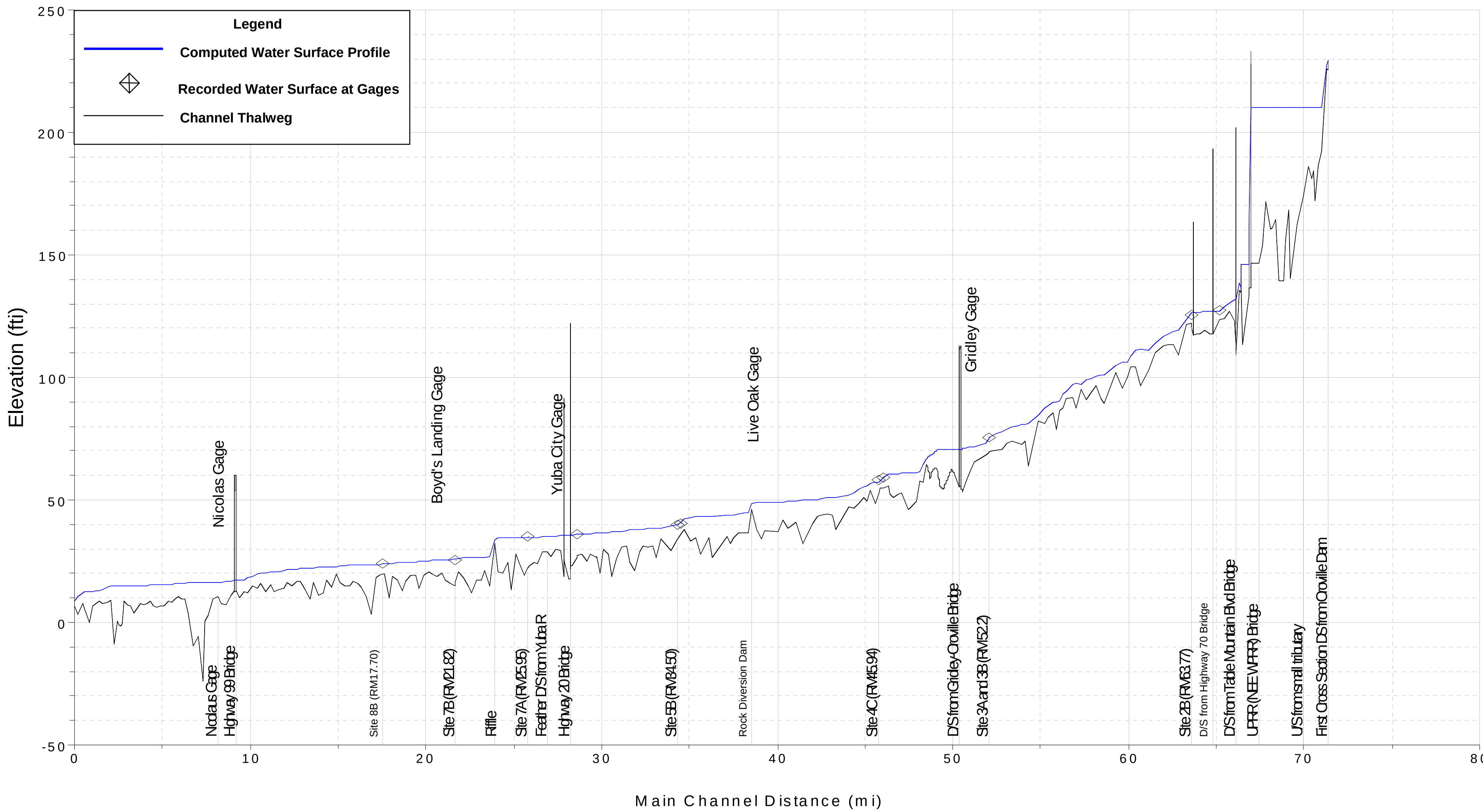

Figure 2.5-5. Validation water surface profile